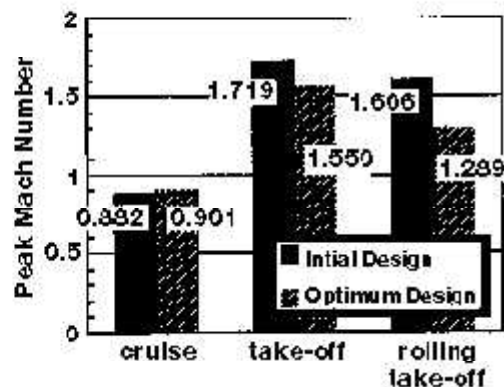
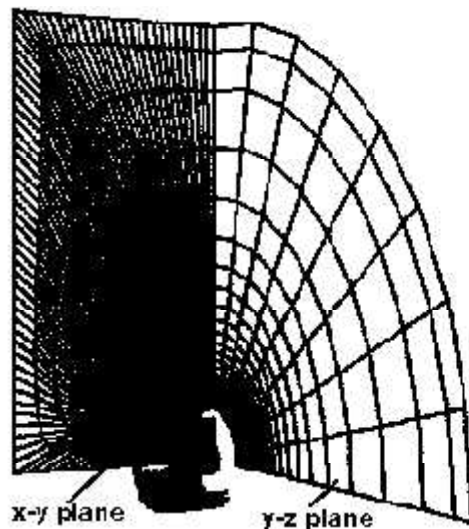


CFD-Based Design Optimization Tool Developed for Subsonic Inlet

The traditional approach to the design of engine inlets for commercial transport aircraft is a tedious process that ends with a less-than-optimum design. With the advent of high-speed computers and the availability of more accurate and reliable computational fluid dynamics (CFD) solvers, numerical optimization processes can effectively be used to design an aerodynamic inlet lip that enhances engine performance. The designers' experience at Boeing Corporation showed that for a peak Mach number on the inlet surface beyond some upper limit, the performance of the engine degrades excessively. Thus, our objective was to optimize efficiency (minimize the peak Mach number) at maximum cruise without compromising performance at other operating conditions.

Using a CFD code NPARC, the NASA Lewis Research Center, in collaboration with Boeing, developed an integrated procedure at Lewis to find the optimum shape of a subsonic inlet lip and a numerical optimization code, ADS. We used a GRAPE-based three-dimensional grid generator to help automate the optimization procedure. The inlet lip shape at the crown and the keel was described as a superellipse, and the superellipse exponents and radii ratios were considered as design variables.

Three operating conditions: cruise, takeoff, and rolling takeoff, were considered in this study. Three-dimensional Euler computations were carried out to obtain the flow field. At the initial design, the peak Mach numbers for maximum cruise, takeoff, and rolling takeoff conditions were 0.88, 1.772, and 1.61, respectively. The acceptable upper limits on the takeoff and rolling takeoff Mach numbers were 1.55 and 1.45. Since the initial design provided by Boeing was found to be optimum with respect to the maximum cruise condition, the sum of the peak Mach numbers at takeoff and rolling takeoff were minimized in the current study while the maximum cruise Mach number was constrained to be close to that at the existing design.



Left: Inlet and sample three-dimensional grid in two planes. Alternate grid lines shown along the radial direction. Right: Comparison of peak Mach numbers at initial and optimum designs.

With this objective, the optimum design satisfied the upper limits at takeoff and rolling takeoff while retaining the desirable cruise performance. Further studies are being conducted to include static and cross-wind operating conditions in the design optimization procedure. This work was carried out in collaboration with Dr. E.S. Reddy of NYMA, Inc.

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